ULTRABARRIER SUBSTRATES

BACKGROUND OF THE INVENTION

The present invention relates generally to barrier coatings, and more particularly to barrier coatings having improved barrier properties.

Many different types of products are sensitive to gas and liquids, which can cause deterioration of the product or render it useless, including electronics, medical devices, and pharmaceuticals. Barrier coatings have been included in the packaging for these environmentally sensitive products to protect them from gas and liquid transmission. As used herein, the term environmentally sensitive means products which are subject to degradation caused by permeation of environmental gases or liquids, such as oxygen and water vapor in the atmosphere or chemicals used in the processing, handling, storage, and use of the product.

Plastics are often used in product packaging. However, the gas and liquid permeation resistance of plastics is poor, often several orders of magnitude below what is required for product performance. For example, the oxygen transmission rates for materials such polyethylene terephthalate (PET) are as high as 1550 cc/m^2/day/micron of thickness (or 8.7 cc/m^2/day for 7 mil thickness PET), and the water vapor transmission rates are also in this range. Certain display applications using environmentally sensitive display devices, such as organic light emitting devices, require encapsulation that has a maximum oxygen transmission rate of 10^{-4} to 10^{-2} cc/m^2/day, and a maximum water vapor transmission rate of 10^{-5} to 10^{-6} g/m^2/day.

Barrier coatings have been applied to plastic substrates to decrease their gas and liquid permeability. Barrier coatings typically consist of single layer thin film inorganic materials, such as Al, SiO_x, AlO_x, and Si_3N_4 vacuum deposited on polymeric substrates. A single layer coating on PET reduces oxygen permeability to levels of about 0.1 to 1.0 cc/m^2/day, and water vapor permeability to about 0.1 to 1.0 g/m^2/day, which is insufficient for many display devices.

Barrier coatings which include alternating barrier layers and polymeric layers have been developed. For example, U.S. Pat. Nos. 5,607,789 and 5,681,666 disclose a moisture barrier for an electrochemical cell tester. However, the claimed moisture barrier ranges from 2 to 15 micrograms/in^2/day which corresponds to a rate of 0.003 to 0.023 g/m^2/day. U.S. Pat. No. 5,725,909 to Shaw et al. discloses a coating for packaging materials which has an acrylate layer and an oxygen barrier layer. The oxygen transmission rate for the coating was reported to be 0.1 cc/m^2/day at 23° C. and the water vapor transmission rate was reported to be 0.01 g/m^2/day in D. G. Shaw and M. G. Langlois, Society of Vacuum Coaters, 37th Annual Technical Conference Proceedings, p. 240–244, 1994. The oxygen transmission rates for these coatings are inadequate for many display devices.

Thus, there is a need for an improved, lightweight, barrier coating, and for methods for making such a barrier coating.

SUMMARY OF THE INVENTION

The present invention meets these needs by providing a barrier assembly and a method for making such an assembly. The barrier assembly includes at least one barrier stack having at least one barrier layer and at least one polymer layer. The barrier stack has an oxygen transmission rate of less than 0.005 cc/m^2/day at 23° C. and 0% relative humidity, and an oxygen transmission rate of less than 0.005

cc/m^2/day at 38° C. and 90% relative humidity. It also preferably has a water vapor transmission rate of less than 0.005 g/m^2/day at 38° C. and 100% relative humidity.

Preferably, the barrier layers of the barrier stacks are substantially transparent. At least one of the barrier layers preferably comprises a material selected from metal oxides, metal nitrides, metal carbides, metal oxynitrides, metal oxyborides, and combinations thereof.

The barrier layers can be substantially opaque, if desired. The opaque barrier layers are preferably selected from opaque metals, opaque polymers, and opaque ceramics.

The barrier assembly can include a substrate adjacent to the at least one barrier stack. By adjacent, we mean next to, but not necessarily directly next to. There can be additional layers intervening between the adjacent layers. The substrate can either be flexible or rigid. It is preferably made of a flexible substrate material, such as polymers, metals, paper, fabric, and combinations thereof. If a rigid substrate is used, it is preferably a ceramic (including glasses), a metal, or a semiconductor.

The polymer layers of the barrier stacks are preferably acrylate-containing polymers. As used herein, the term acrylate-containing polymers includes acrylate-containing polymers, methacrylate-containing polymers, and combinations thereof The polymer layers can be the same or different.

The barrier assembly can include additional layers if desired, such as polymer smoothing layers, scratch resistant layers, antireflective coatings, or other functional layers.

The present invention also involves a method of making the barrier assembly. The method includes providing a substrate, and placing at least one barrier stack on the substrate. The barrier stack includes at least one barrier layer and at least one polymer layer.

The at least one barrier stack can be placed on the substrate by deposition, preferably vacuum deposition, or by laminating the barrier stack over the environmentally sensitive device. The lamination can be performed using an adhesive, solder, ultrasonic welding, pressure, or heat.

Accordingly, it is an object of the present invention to provide a barrier assembly, and to provide a method of making such a barrier assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section of one embodiment of the barrier assembly of the present invention.

FIG. **2** is a cross-section of an encapsulated device made using the barrier assembly of the present invention.

DESCRIPTION OF THE INVENTION

One embodiment of the barrier assembly of the present invention is shown in FIG. **1**. The barrier assembly is supported by a substrate **105**. The substrate **105** can be either rigid or flexible. A flexible substrate can be any flexible material, including, but not limited to: polymers, for example, polyethylene terephthalate (PET), polyethylene naphthalate (PEN), or high temperature polymers, such as polyether sulfone (PES), polyimides, or Transphan™ (a high glass transition temperature cyclic olefin polymer available from Lofo High Tech Film, GMBH of Weil am Rhein, Germany); metal; paper; fabric; and combinations thereof. Rigid substrates are preferably glass, metal, or silicon.

There are scratch resistant layers **110** on either side of the substrate **105** to protect it. When a scratch resistant layer is